

# Particle Transfer from Magnetic Plugs

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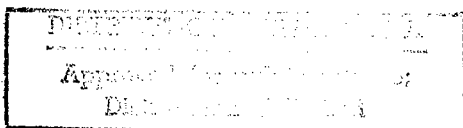
**Abstract:** Magnetic drain plugs have been in use for over thirty years and have developed from simple magnets to self indicating devices. The purpose of this paper is to review the debris transfer from the magnetic plug and suggest procedures to reduce the operator effort, increase the efficiency of the debris transfer and to improve measurement repeatability. Three new procedures are also proposed for review : the fitting of a plastic or metallic sheath, neutralisation of the magnetic attraction and the use of wax to remove the debris.

**Keywords:** Condition monitoring; magnetic drain plugs; wear debris analysis.

**Introduction:** Magnetic plugs have been in use for over thirty years and have developed from simple magnets to self indicating devices e.g. QDM - Quantitative Debris Monitor [1]. In many current applications, both civil and military, a standard magnetic plug which has to be removed from the system for visual inspection is still utilised and the method of particle transfer from the plug has basically remained unchanged : an initial solvent cleaning process followed by an application of sellotape (Figure 1). Optical microscopy and X-Ray Fluorescence have enhanced particle recognition by determining the material composition of the collected debris. The advent of computer imaging analysis, numerical and neural network analysis are currently generating expert systems to automatically classify the wear debris generated during the wear process.[2].

It is the purpose of this paper to review the transfer procedures of the attached debris from the magnetic plug and suggest modifications to reduce the operator effort, increase the efficiency of the debris extraction and to improve measurement repeatability. Three new techniques are also proposed for review : the fitting of a plastic or metallic sheath, neutralisation of the magnetic attraction and the use of wax to remove the debris.

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implementation have created difficulties due to the absence of an equally efficient alternative to the chlorinated hydrocarbons. Alternatives have

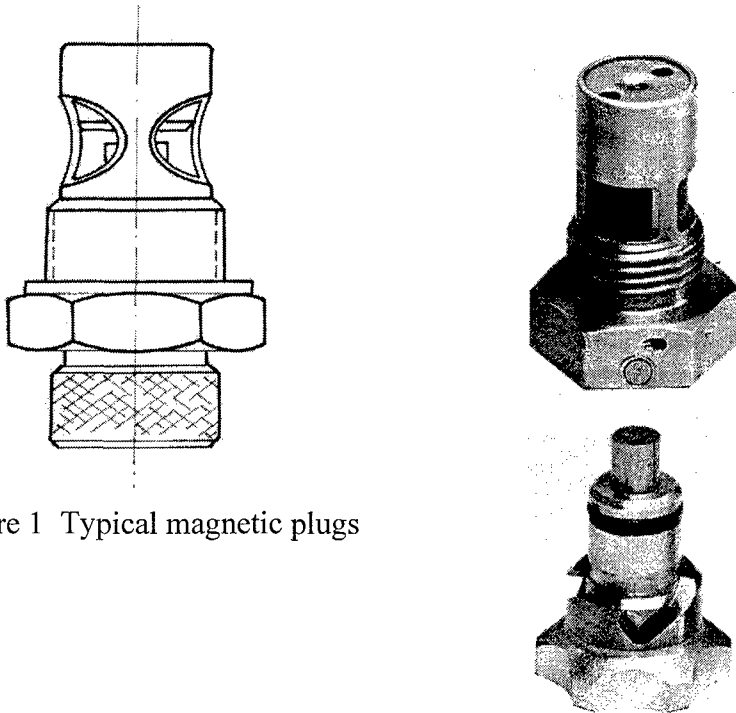


Figure 1 Typical magnetic plugs

however been proposed and accepted by the TSC of JOAP, Pensacola [3]. After removal of all traces of the lubricant or hydraulic fluid from the face of the magnetic plug a strip of sellotape is pressed against the plug face and peeled away with the wear debris and contaminants attached to the adhesive face of the sellotape. At this stage the tape is attached to a record card and may then be placed on a sensor which measures the ferrous content. This stage has posed numerous problems to the operator due to the position sensitivity of the ferrous debris on the sensor. The following procedure is proposed which overcomes this problem.

This procedure suggests the use of a light box' similar to the box used for viewing photographic slides.

Once the debris has been 'wiped' from the magnetic plug using sellotape, the strip with the attached debris may be positioned on the record card in the appropriate centralised position aided by the back-lighting from the light box. The debris is clearly visible in a centralised position and will obviate the presence of operator sensitivity and ensure a more consistent measurement when utilising a 'Wear Debris Tester instrument.' [4]

An alternative method which has shown superior sensitivity, more consistent and hence repeatable results is the use of an adapter with the Ferrous Debris Monitor (Particle Quantifier)[5]. The sellotape strip, with the extracted debris attached, as described above, is pressed on to the adapter shown in Figure 2. The debris is centred within the annulus using the light box method. The adapter is then placed on the Ferrous Debris Monitor for

measurement of the ferrous debris content with no further preparation (Figure 3). Repeated tests and rotation of the adapter have shown repeatability of better than 3 per cent for the PQ Index.

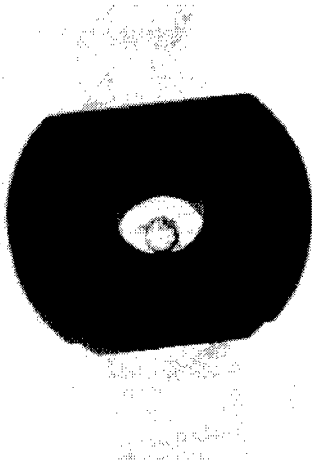


Figure 2 Adaptor for debris measurement



Figure 3 Ferrous Debris Monitor (PQP)

Subsequent microscope examination of the debris is facilitated by the debris being attached to the adhesive side of the sellotape. Auto focusing of the optical microscope is maintained and viewing of the debris does not therefore have to be carried out through the sellotape, a procedure which distorts the image. Use of Mylar tape instead of the standard sellotape enables the particles to be prepared for electron microscope examination and XRF analysis without further treatment.

**Reduction of Magnetic Attraction:** Particles on the magnetic plug are often distributed around the flank of the plug as well as on the face of the plug. In order to remove these particles the sellotape has to be wrapped around the flank. The attached debris often results in an uneven particle distribution.

A device has been developed to both scrape the flank of the plug and at the same time reduce the magnetic attractive force at the plug face. This device is illustrated in the Figure 4.

The steps to remove the particles are simple. Firstly, the magnetic plug is located on a spring loaded seat, the 'jaws' of the clamp are then closed leaving the plug face proud of the clamp by several millimetres. Surrounding the plug with soft iron effectively reduces the magnetic field - a reduction in excess of 80 per cent is achieved. A sellotape strip is placed over the protruding plug end face and with pressure from the thumb the plug is pressed down on the spring loaded seat such that the plug flanks are scraped clean and all these particles together with the particles attached to the plug face are attached by the

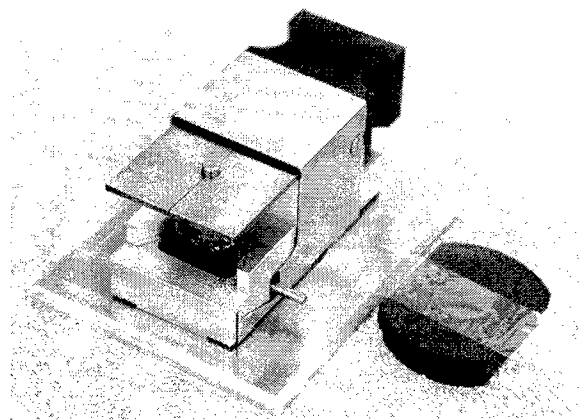
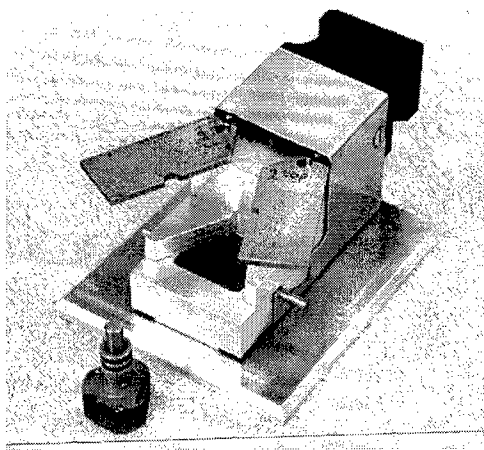


Figure 4 Device for the reduction of magnetic attraction and particle removal

adhesive of the sellotape. The reduction of the magnetic field enables all the particles to be more effectively removed and concentrated in a circular region. The use of a soft rubber stopper has been found to be more effective than pressing with a finger or thumb ensuring removal of all the debris. The sellotape with the particles attached may then be positioned centrally on the adapter and measured using the PQ analyser. The field strength of the magnetic plug, when removed from this device, returns to its original strength.

**Sleeve Technique:** Most of the magnetic plugs in use have a cylindrical shape and are over one centimetre long. The plug fitting is a self sealing device such that when the plug is either fitted or removed, the housing self seals so that no fluid is allowed to escape. The housing allows the plug face to be positioned directly in the fluid stream or at an elbow located in the fluid circuit.

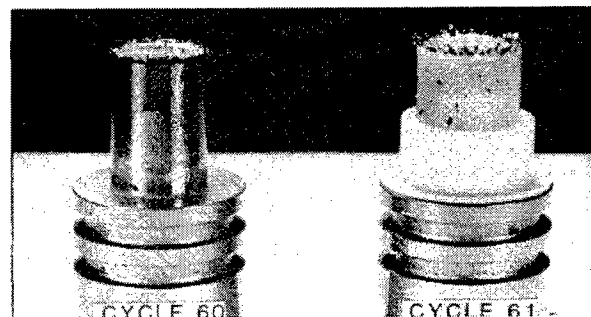
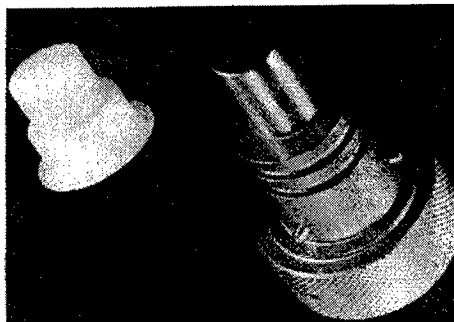


Figure 5 Magnetic plug sleeves

To facilitate the removal of particles from the plug a sleeve may be fitted as shown in Figure 5 [6]. The plug material may be either non magnetic plastic or mild steel. A mild

steel sleeve has however, been found to be more effective. The mild steel sleeve maintains a low level of magnetic attraction when removed from the magnetic plug. A slight tap of the sleeve is then sufficient to remove all the particles which may then be collected in a small plastic cup. The PQ analyser then measures the ferrous content of the particles.

Tedeco, the manufacturers of magnetic plugs, have also developed a sleeve adaptation to their standard fitting. Figure 6 illustrates their design [7].

A withdrawable magnet is located inside the plug housing. This housing with its magnet is released from the gearbox in the normal way using the bayonet fitting. The housing is then positioned over a collector fixture and the magnet removed from the housing. The debris is attracted to the collector fixture by the transfer magnetic.

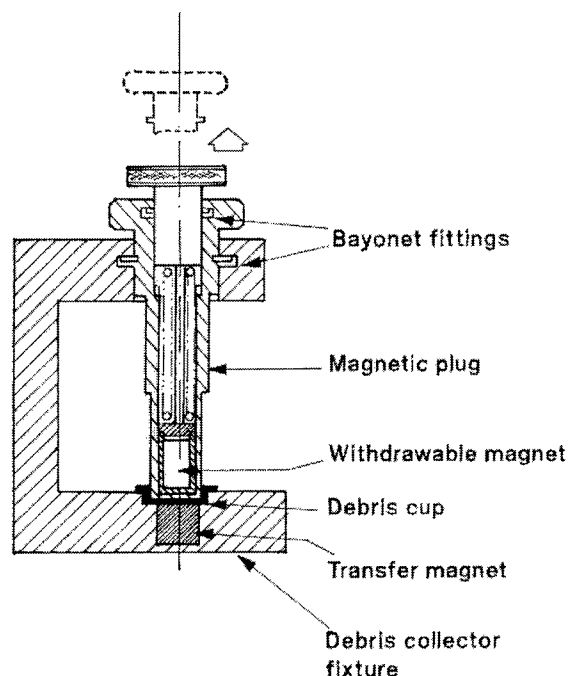


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**Particle Presentation:** One of the problems with optical and electron microscopic examination of wear particles collected from a magnetic plug is the overlapping of the particles. Computerised image analysis of these overlapping particles results in erroneous data. This problem may be overcome by placing the plastic cup containing the particles removed from the plug on a rubber magnetic pad. Gentle sliding motion of the cup over

the pad rearranges the particles in rows more suitable for microscopic examination (see Figure 7).

A further advantage of this method is that the particles are unlikely to be altered by pressure as would be the case when pressure is applied to the sellotape to effect the adhesion between tape and particle.

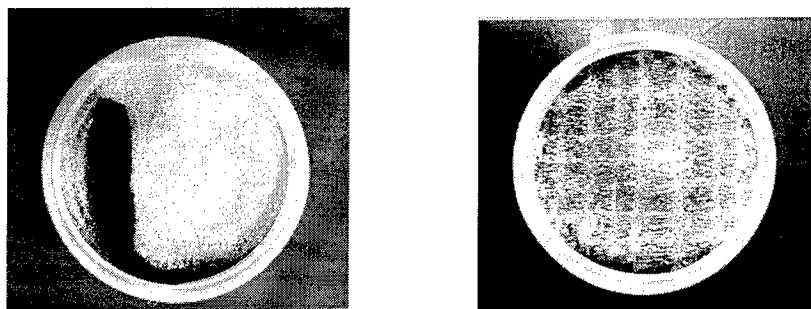


Figure 7 Particle separation using a rubber magnetic pad

**Wax Method [8]:** A further adaptation of the sleeve technique is the use of wax to surround the plug after its removal from the housing.

Upon the removal of the magnetic plug, the end which has the debris attached is dipped into molten wax and repeatedly dipped three or four times until a coating is formed in a similar way to the formation of a wax candle. The wax bath would have been heated and maintained at approximately 60 degrees C. The wax used in this evaluation was standard paraffin wax although it may be substituted for other waxes, resins or gels which are used in model or investment casting.

The solid wax surrounding the magnetic plug may be slid along the plug until the capsule is free of the plug. Removal of the wax is facilitated if the plug, after removal from the housing, has not been cleaned with solvent. The oil retained on the surface of the plug acts as a release agent. The wax capsule within which the debris from the plug is embedded may then be accurately centred above the measuring head of the Ferrous Debris Monitor (PQ). This procedure avoids the operator optimising the debris position on the measuring instrument.

If the debris has to be viewed by either optical or electron microscope it may be separated from the wax by adding a small quantity of petroleum spirit in a suitable container. Agitation of the container facilitates the dissolution of the wax. A magnet held outside the container allows the solution to be decanted leaving the particles free to be viewed. If a

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**Conclusions:** A number of methods for the removal of debris from magnetic drain plugs has been presented. These methods are at present being tested in the field and it is the field operators who will judge the efficacy of debris removal and examination by these methods..

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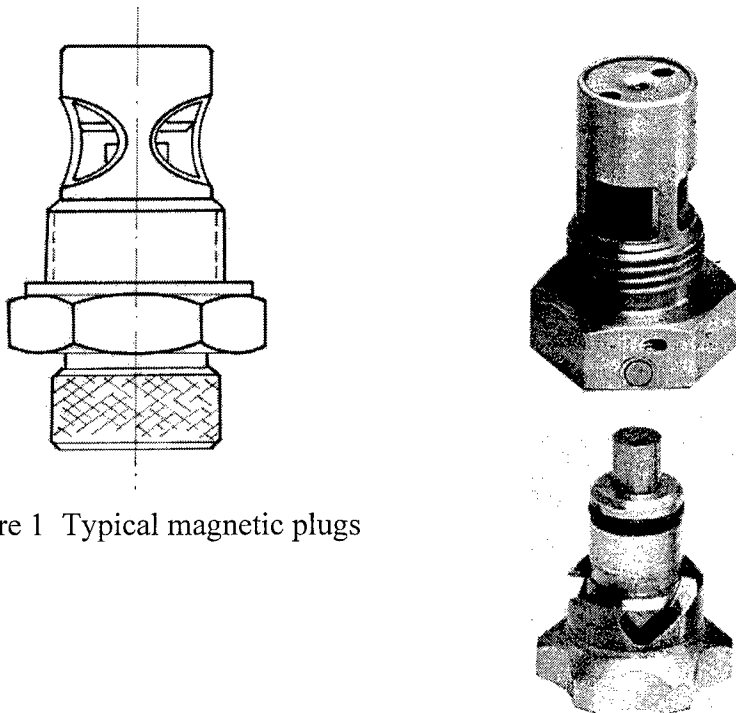


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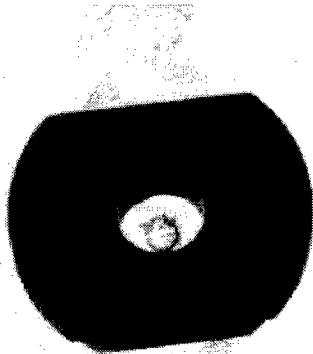


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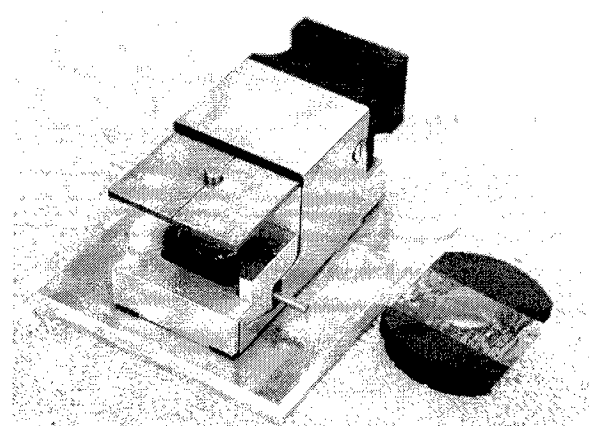
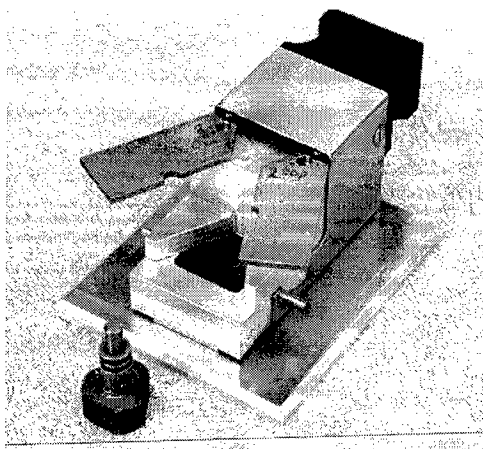


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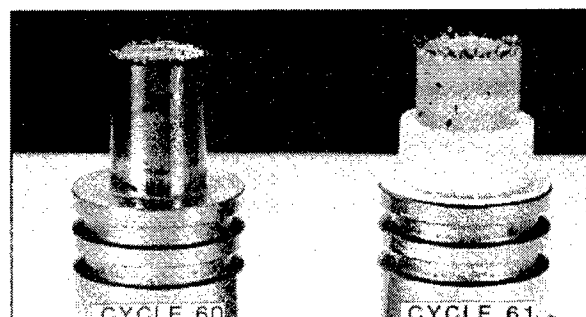
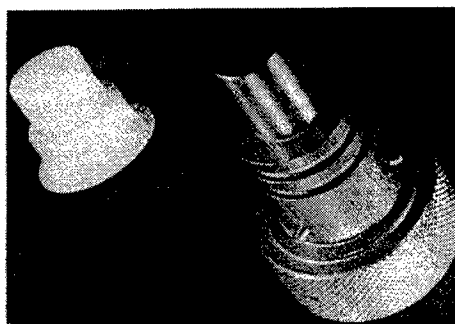


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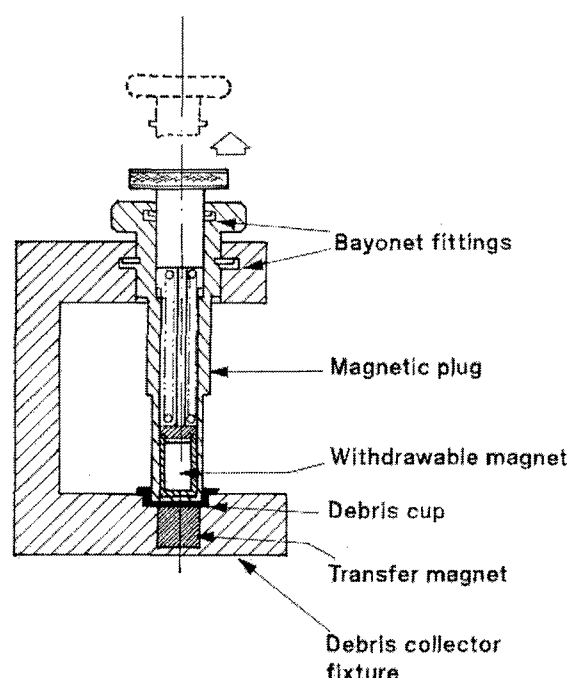


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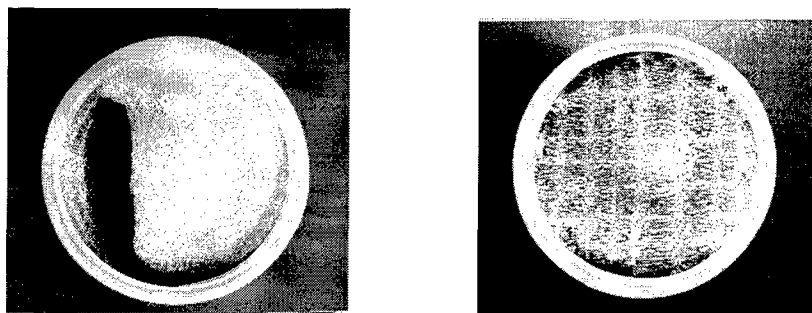


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